

# Sounding Rocket Working Group

SRPO Summary  
December 20, 2006  
Philip Eberspecker





# Presentation Outline

- Mission Results Summary (since last meeting)
- FY07-FY08 Manifest
- Anomaly Investigation Status
- Poker Status (Libby West)
- Accomplishments
- Foreign Missions
- Student Flight Opportunities/Concepts
- Budget
- Technology Update
- Rocket Motor Status
- Findings from January SRWG Meeting
- Brant Return to Flight (John Hickman)
- Mesquito Status (Dave Krause)
- Next Generation ACS (Brett Vincent)





# Mission Results Since Last SRWG

- 9 Total Missions
  - 3 Science
    - Woods - WSMR (failure)
    - Judge - WSMR (success)
    - Cash - WSMR (success)
  - 1 Educational
    - SubSEM (success)
  - 1 Technology
    - Brant return to flight (success)
  - 4 Reimbursable
    - 2 complex target missions (success)
    - 2 Army Infrasound missions (success)



		FY 2006	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
#	Vehicle Type	Mission												
		<b>WALLOPS ISLAND</b>												
1	Test Vehicle	HICKMAN/NASA			▲	Success								
2	Test Vehicle	HICKMAN/NASA												
3	Orion	JUSTIS/NASA									▲	Success	Success	▲
		<b>WSMR</b>												
4	Black Brant IX	KANKELBORG/MONTANA ST. UNIV.												
5	Terrier Orion	SEYBOLD/JPL												
6	Black Brant IX	RABIN/GSFC												
7	Test Vehicle	COSTELLO/NASA-NSROC												
8	Black Brant IX	MCCAMMON/UNIV. OF WISCONSIN	TBD											
		<b>NORWAY</b>												
9	Terrier Orion	WHEELER/PENN STATE UNIVERSITY												
		<b>REIMBURSABLE MISSIONS</b>												
10	Terrier Oriole	WINSTEAD/NAWC (HAWAII)		▲	Success									
11	Orion	WINSTEAD/NAWC (WSMR)		▲	Success									
12	Terrier Orion	WINSTEAD/NAWC (WSMR)		▲	Success									
13	Terrier Orion	WINSTEAD/NAWC (WSMR)		▲	Success									
14	Orion	WINSTEAD/NAWC (WSMR)												
15	Orion	WINSTEAD/NAWC (WSMR)												
16	Terrier Orion	WINSTEAD/NAWC (HAWAII)												
17	Terrier Orion	WINSTEAD/NAWC (HAWAII)												
18	Terrier Orion	WINSTEAD/NAWC (WSMR)												
19	Terrier Orion	WINSTEAD/NAWC (WSMR)												
20	Terrier Orion	WINSTEAD/ARAV (WSMR)												
21	Terrier Orion	WINSTEAD/ARAV (WSMR)												
22	Orion	WINSTEAD (WSMR)	TBD											
23	Orion	WINSTEAD (WSMR)	TBD											
24	Black Brant IX	AUDENAERT/THAAD (WSMR)												
25	Black Brant IX	AUDENAERT/THAAD (WSMR)												

100% success in FY06



# FY07 Launch Schedule



FY 2007			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
#	Vehicle Type	Mission												
<b>WALLOPS ISLAND</b>														
1	Black Brant IX	EARLE/UNIV. OF TEXAS-DALLAS							△					
2	Terrier Orion	PLAYER/LARC							△					
<b>WSMR</b>														
3	Black Brant IX	JUDGE/USC		▲										
4	Black Brant IX	WOODS/UNIVERSITY OF COLORADO	▲											
5	Black Brant IX	CASH/UNIVERSITY OF COLORADO		▲										
6	Black Brant IX	HASSLER/SWRI								△				
7	Black Brant IX	MCCANDLISS/JHU									△			
8	Black Brant IX	CHAKRABARTI/BOSTON UNIVERSITY						△						
9	Test Flight	COSTELLO/NASA-NSROC						△						
10	Terrier Orion	DAVIS/MSFC									△			
11	Terrier Orion	MOSES/NRL										△		
<b>NORWAY</b>														
12	Terrier Orion	ROBERTSON/UNIV. OF COLORADO											△	
13	Terrier Orion	ROBERTSON/UNIV. OF COLORADO											△	
<b>PFRR</b>														
14	Black Brant XII	LESSARD/UNIV. OF NEW HAMPSHIRE				△								
15	Black Brant VB	LARSEN/CLEMSON UNIVERSITY				△								
16	Black Brant IX	LARSEN/CLEMSON UNIVERSITY				△								
17	Terrier Orion	LARSEN/CLEMSON UNIVERSITY				△								
18	Terrier Orion	LARSEN/CLEMSON UNIVERSITY				△								
19	Terrier Orion	CRAVEN/UNIVERSITY OF ALASKA					△							
20	Terrier Orion	CRAVEN/UNIVERSITY OF ALASKA					△							
21	Terrier Orion	CRAVEN/UNIVERSITY OF ALASKA					△							
22	Black Brant XII	CRAVEN/UNIVERSITY OF ALASKA					△							
23	Black Brant XII	LABELLE/DARTMOUTH COLLEGE					△							
<b>REIMBURSABLE MISSIONS</b>														
1	Black Brant IX	MARTI/USAF-ABL (WSMR)							△					
2	Black Brant IX	MARTI/USAF-ABL (WSMR)							△					
3	Black Brant IX	MARTI/USAF-ABL (WSMR)							△					



# FY08 Manifest



	Mission	Launch Date	Site	PI	Comments
1	36.XXX	Nov/Dec	WSMR	McCandliss	LIDOS #2 – Orion target    Confirmed 10-02-06
2	35.036	Dec	Andoya	Kletzing	
3	40.018	Dec	Andoya	Kletzing	
4	35.XXX	Jan	Andoya	Kintner	
5	36.213	Feb	WSMR	<del>Porter</del> Davis	Place holder – future uncertain    10-02-06
6	36.XXX	April	WSMR	McCandliss	FORTRESS Payload - New
7	36.226	May	WSMR	Bock	Possible slip indicated by HQ on 10-02-06...
8	36.219		WSMR	Hassler	Slip indicated by HQ on 10-02-06
9	36.XXX		WSMR	Judge	Possible new mission – HQ input 10-02-06
10	36.XXX		WSMR	Rabin	Possible new mission – HQ input 10-02-06
11					
12					
13					
	41.XXX	TBD	WSMR	Erdman	
	36.207	TBD	WSMR	Cruddance	Instrument Issues – place holder
	36.173	TBD	WSMR	Nordsieck	



# Active Mishap Investigation Boards (MIB)



Failure	AIB lead	Status
BBXII Vehicle Failure – 40.017 (Poker 2005)	NASA (Nelson)	Closed -
Celestial ACS Test Flight (12.058)	NSROC	Closed -
Parachute Anomaly (36.203/Rabin)	NSROC	Closed -
Experiment Failure (36.233/Woods)	Univ. of Colorado	Report submitted to SRPO. SRPO has asked for more detail on root cause(s) and recommendations





# Poker Campaign Status



**Campaign Manager (CM) Libby West**  
**Deputy Campaign Manager (DCM) Brian Hall**

*Scheduled Campaign Window: January, February, March (BU) 2007*

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# Payload Status – January Missions



- Larsen
  - Payloads and GSE shipped December 18, 2006
  - MRR follow up Review completed December 19, 2006
  - Field Integration begins December 28, 2006
  - 21.138
    - ACS noise issue – traced to wiring harness which was replaced
    - GSFC hinges cleaned up, pre-amps replaced, and HF electric field booms repaired
    - Follow up T&E complete at WFF
  - 36.234
    - A few instrument issues emerged during test and integration
    - GSFC hinges cleaned up, solder connections repaired
    - Follow up T&E complete at WFF for GSFC section
    - Aerospace instrumentation repairs underway and section will be shipped directly to PFRR for field integration
    - Corrective action has been taken in all cases
  - 41.064 & 41.065
    - No significant issues
- Lessard
  - Only minor issues encountered during integration and test
  - Field Integration November 28 – December 15 - Complete



# Payload Status – February Missions



- LaBelle
  - Combination TM/GPS antenna had null issues
    - Problem traced to PSL workmanship issues
    - Replacement to be provided
  - Problems encountered during vibration
    - Payload repairs complete, followed up with Pre-Vibe Sequence testing.
    - Vibration underway December 19.
- Craven
  - Complete with Vibration and Post-Vibe Sequence testing for all payloads
  - Bend test, mag cal, outdoor GPS testing in various stages for all payloads
  - Corona test remains for all payloads







# Range Instrumentation Status



- Instrumentation Verification/Validation complete September 2006.
- Fixed TM
  - Redstone, 16 ft – GREEN
  - TOTS – repair of Auto track in progress
  - 11M – System GREEN - finalizing contract details for mission support
- Mobile TM
  - 2 x 7M Antennas and Supervan - GREEN
- Radar
  - Radar 8 and Radar 10 – GREEN
- Command Van
  - System – GREEN
  - Look Angles for January Missions - Complete
  - Look Angles for February Missions - Awaiting final trajectory data – will receive upon completion of T&E
- Staffing - Green



# Range Safety Status

- Ground Safety
  - All Risk Analysis Reports complete
  - All Ground Safety Plans complete – Except Craven 35.037 – In signature loop
  - 35.037 TTS testing procedures being finalized
- Flight Safety
  - January Missions
    - All Final Risk Analysis Reports complete – Except Larsen 36.234 – In signature loop
    - All Final Flight Safety Plans complete – Except Larsen 36.234 - In signature loop
  - February Missions
    - All Preliminary Risk Analysis Reports in signature loop – Except Craven 35.037 – In progress
    - All Preliminary Flight Safety Plans in signature loop – Except Craven 35.037 – In progress
- Outstanding Items
  - Still refining TTS limit lines and mission rules for Craven 35.037
  - All NASA Safety criteria are met, PFRR criteria more strict and will require waivers – working with Poker – all indications favorable for waiver approval
  - Waiver request in progress



# Accomplishments

(Phil Eberspecker)



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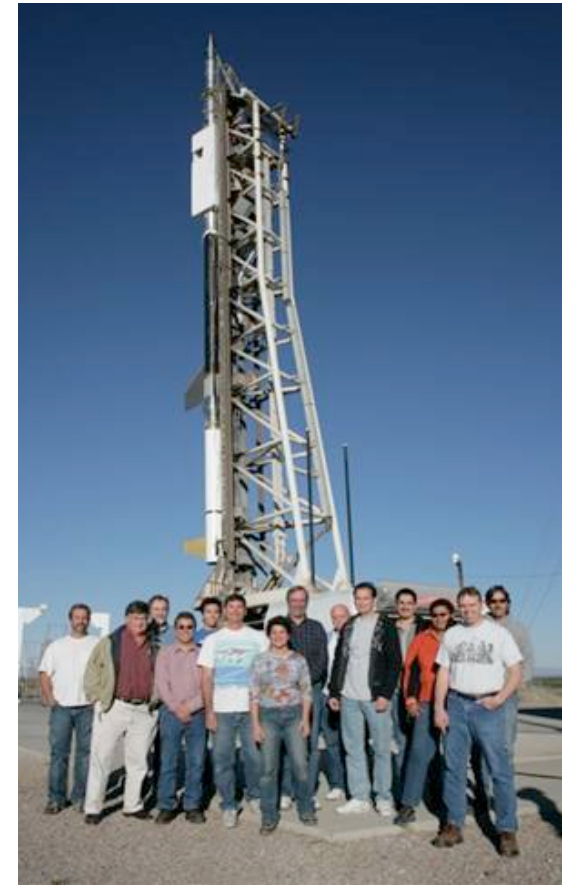
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# Accomplishments - Flights



- Woods/36.233
  - WSMR: Oct 28, 2006
  - Mission Failure
  - Multiple field deployments required
- Judge/36.236
  - WSMR: Nov 7, 2006
  - Mission Successful
- Cash/36.224
  - WSMR: Nov 21, 2006
  - Mission Successful
  - Served as developmental flight for ST-5K Star Tracker
- Wheeler/41.056
  - Andoya: July 1, 2006
  - Mission Success
  - Student mission







# Accomplishments - Subsystems

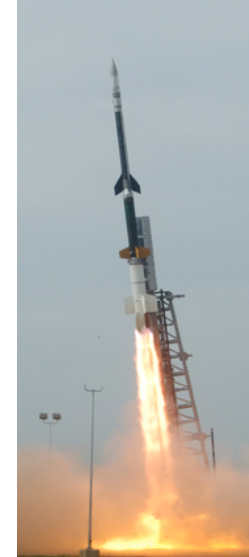


- Celestial ACS Development
  - Test Flight/12.058 – May 22, 2006
  - Star tracker problem
  - *Details will be provided in the afternoon session*
- Star Tracker Development
  - Flown on Cash /36.224
    - Dr. Cash could (and did) achieve science objectives using gyros so mission risk was minimal
  - ST-5K locked on star field and calculated lost in space orientation
  - Unfortunately the ST-5K experienced problems in maintaining lock on the star field
    - Reacquired lock and determined orientation multiple times during the flight
  - *Details will be provided in the afternoon session*
- S-19L
  - Uses the LN-200 gyro
  - Conversion of first two units were paid for by reimbursable missions
  - Both units flown successfully on reimbursable missions

# Accomplishments - Vehicles



- Mesquito Development
  - Motors being “demilitarized” at WSMR
  - DR set for January 10, 2006
- Black Brant Return to Flight (briefing later)
  - Comprehensive review
  - Static firing (Edwards AFB)
  - BBXI flight test
- Brant Fin Coating
  - Coating material no longer available
  - Firex RX-2373 is proposed
    - Characteristics tend to be better than the heritage material
  - WFF Non-Advocate Review conducted on new material (12/5/06)
  - Three recommendations made
    - Better define the fin fight environment (aero & plume heating)
    - Conduct two test flights
    - Provide a vapor barrier to protect the cured Firex coating (i.e. paint the fins)





## Accomplishments – Grd Instrumentation

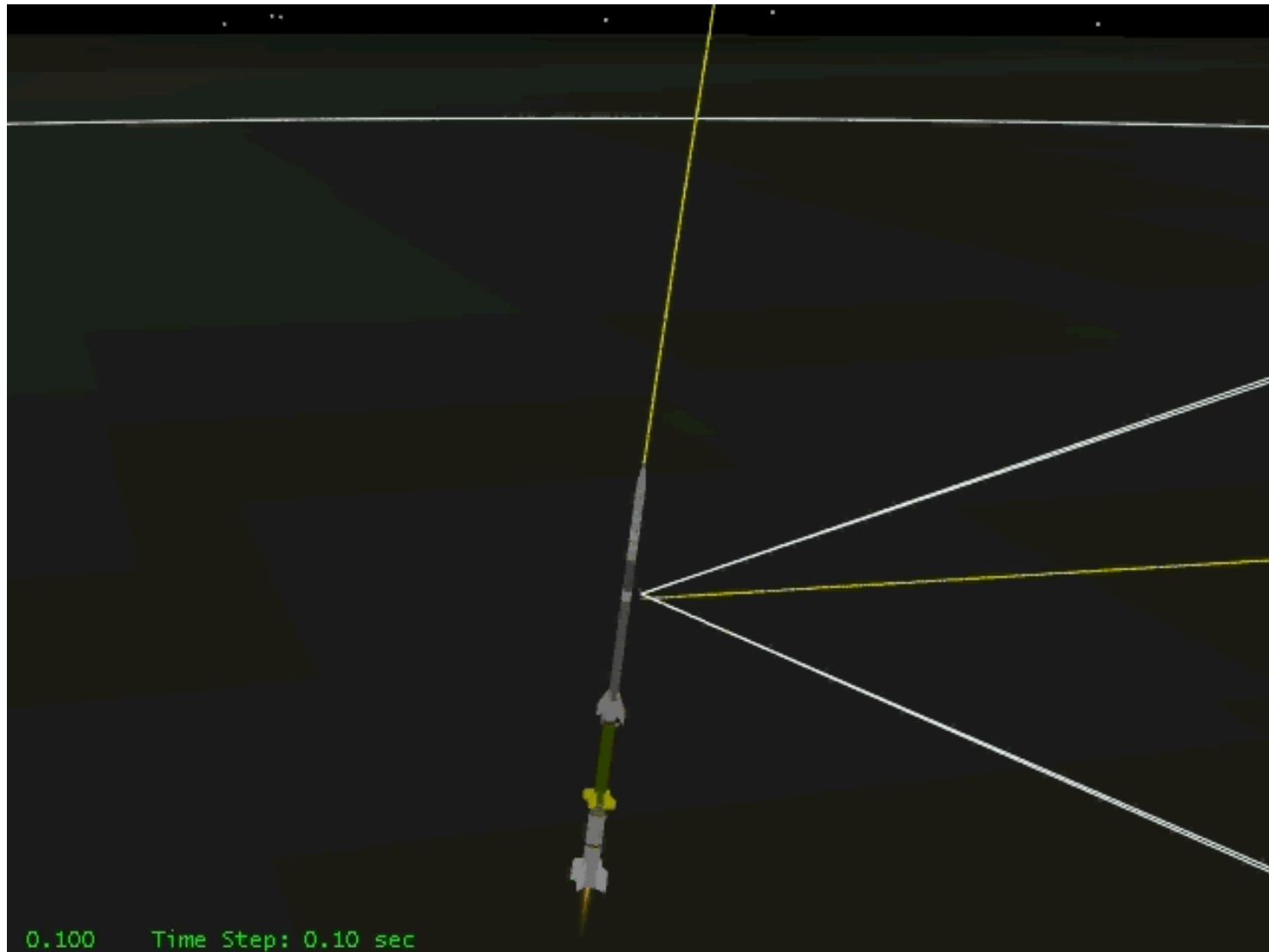


- Dynasonde construction completed
- Attempted to support Earle mission, but system had problems





## Accomplishments – WFF Mission Planning Tool



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# Upcoming Foreign Missions



- Robertson (Andoya, Norway)
  - June/July 2007
  - Collaborative mission with ARR and German/Norwegian ECOMA rocket campaign
  - Under-flight for AIM satellite
  - Two Terrier-Orion rockets
- Kletzing (Andoya, Norway)
  - New SRPO launcher to be installed Summer 2007
  - Launch: December 2007 (FY08)
  - BBX and BBXII
- Kintner (Andoya, Norway)
  - Launch: January 2008
  - BBXII





# Education/Training Flight Opportunities



- Student built rockets
  - Embry-Riddle
  - Air Force Academy
  - Naval Academy
- Space Flight Workshop
  - Concept under development and assessment by SRPO and Colorado Space Grant Consortium
  - Geared towards Space Grant Consortium faculty
  - 7 day workshop at WFF culminating with Orion launch
    - Targeting 40-50 participants
    - Participants pay fee to cover vehicle hardware costs and basic range costs
  - Feeder program for university-level SubSEM flights
    - 4 to 6 schools per flight
    - Participants pay fee to cover mission costs
- NASA Project Management and Systems Engineering Accelerated Experience
  - Intended to provide accelerated “training” for NASA mission managers and systems engineers





# Budget

(Phil Eberspeaker)



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# Status



- FY 07
  - May barely squeak by
  - Virtually no carryover projected
  - Assumes reimbursable labor offsets will cover 26 NSROC WYE's
  - Support 22 SMD flights
  - 10 Brants delivered as part of FY06 purchase
  - 2 Brants delivered as part of planned FY07 purchase
    - 4 other units to be delivered in early FY08
  - No funding for Nihka replacement
  - \$500K allocated to new TTS development/testing
    - Another \$500K allocated for FY08
  - Still some uncertainties with Full Cost Accounting



# Status



- FY 08
  - Deficit Predicted
    - \$6M deficit if...
      - Labor force is maintained
      - No reimbursable missions are conducted
      - Poker and WSMR remain as range options
    - \$3M deficit if...
      - Labor force is maintained
      - Minimal projection of reimbursable missions materializes (4 missions)
      - Poker and WSMR remain as range options
    - Break even if...
      - 8 reimbursable missions obtained
      - Equates to ~\$6M in labor offsets, (or ~51 WYE's)
  - Support 12 SMD flights
  - Delivery of 4 Brants as part of FY07 order
  - Order another 6 Brants w/ delivery in FY08
  - No funding for Nihka replacement
  - \$500K allocated for new TTS development/testing





# Solutions



- Plan A – Additional funding from HQ
  - Would provide stability and allow SRPO/NSROC to focus on scientific missions
- Plan B – NASA/MDA Partnership
  - Potential for 15 target missions per year
  - Would add stability and may lead to expanded capability
  - Significant politics involved - potential for success limited
  - May need to be pushed at higher level (possibly above NASA)
- Plan C – Attempt to land a portion of the work associated with upcoming MDA contracts
  - TSER (NavSea Missile Defense targets)
  - LCAT (MDA Targets and Counter Measures)
- Plan D – Piecemeal reimbursable
  - NASA SDM, NASA Exploration, DoD Targets, DoD Technologies
  - Not predictable





# Technology Development

(Phil Eberspecker)



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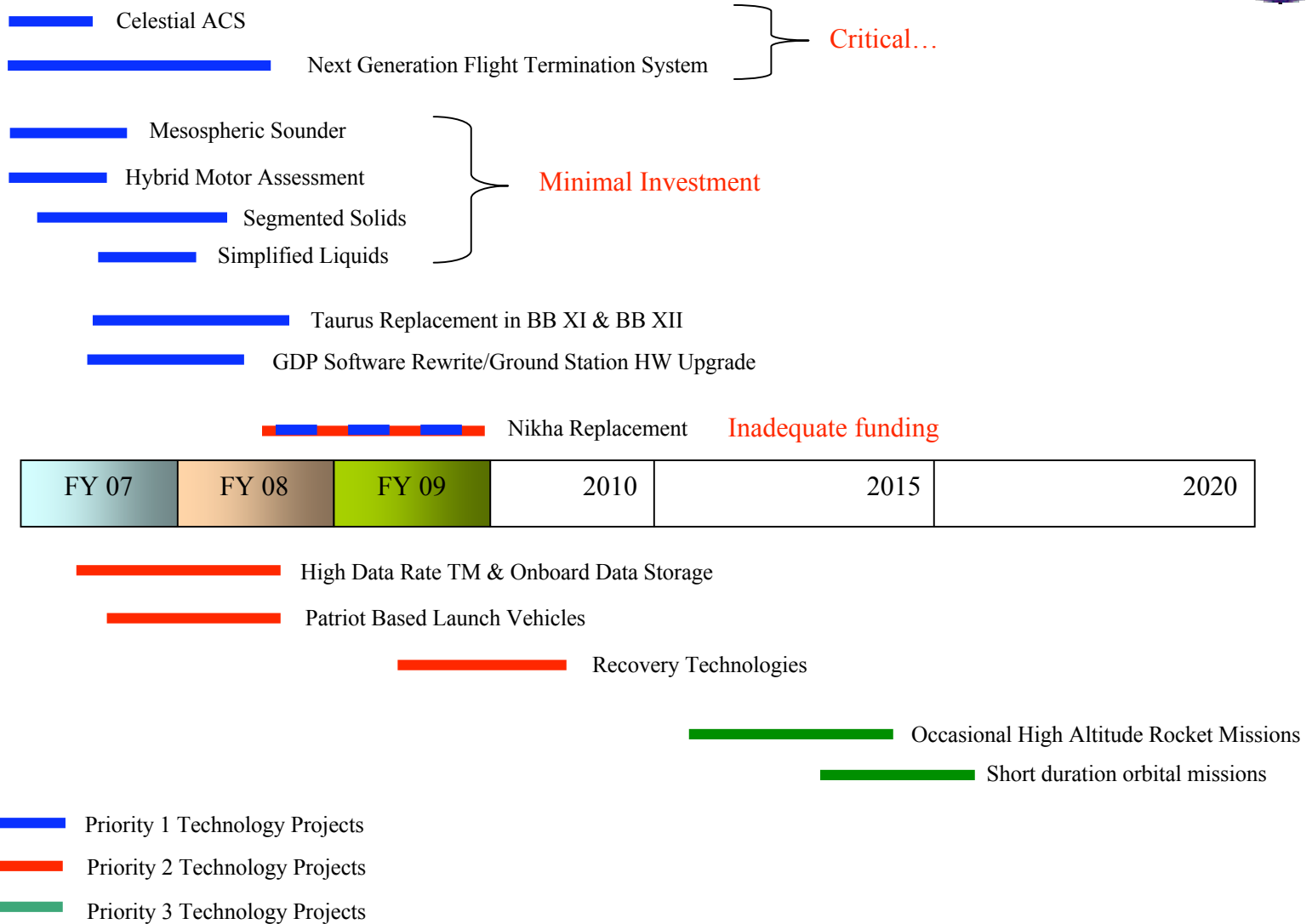
# Technology Program Update



- Limited funding
- Strategy: *Maintain existing capability (as minimum), maximize scientific return, and attract new customers*
  - Maintain existing capabilities
    - ASC Development
      - Velocity Vector ACS
      - Celestial
      - Next Gen Flight Computer
    - Thrust Termination System (TTS) replacement
    - Taurus replacement in BBXI and BBXII stack
  - Maximize scientific return
    - New flight profiles
    - Higher TM rates
  - Expand vehicle capabilities
    - Higher performance motors
    - Large diameter payloads



# Technology Roadmap



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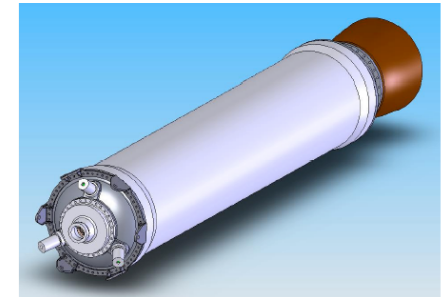
# Technology Program Update



- Low-cost Propulsion

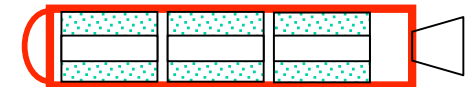
- Hybrid

- Motors tend to be approx 3x longer than solid counterparts
    - SRPO has halted WFF test program (internal funding)
    - SRPO is still working with Ames on flight demonstration (external funding)



- Segmented Solid Rocket Motors

- Use standardized cartridges and leverage propellant pours for larger motor programs (SRB's, DoD)
    - Internal development with industry consultation



- Simplified liquids

- Annular Aerospike engine
    - High speed reciprocating pump - can be throttled
    - Investigating use of a cooperative agreement for initial concept development and demonstration







# Motor Status

(Phil Eberspecker)



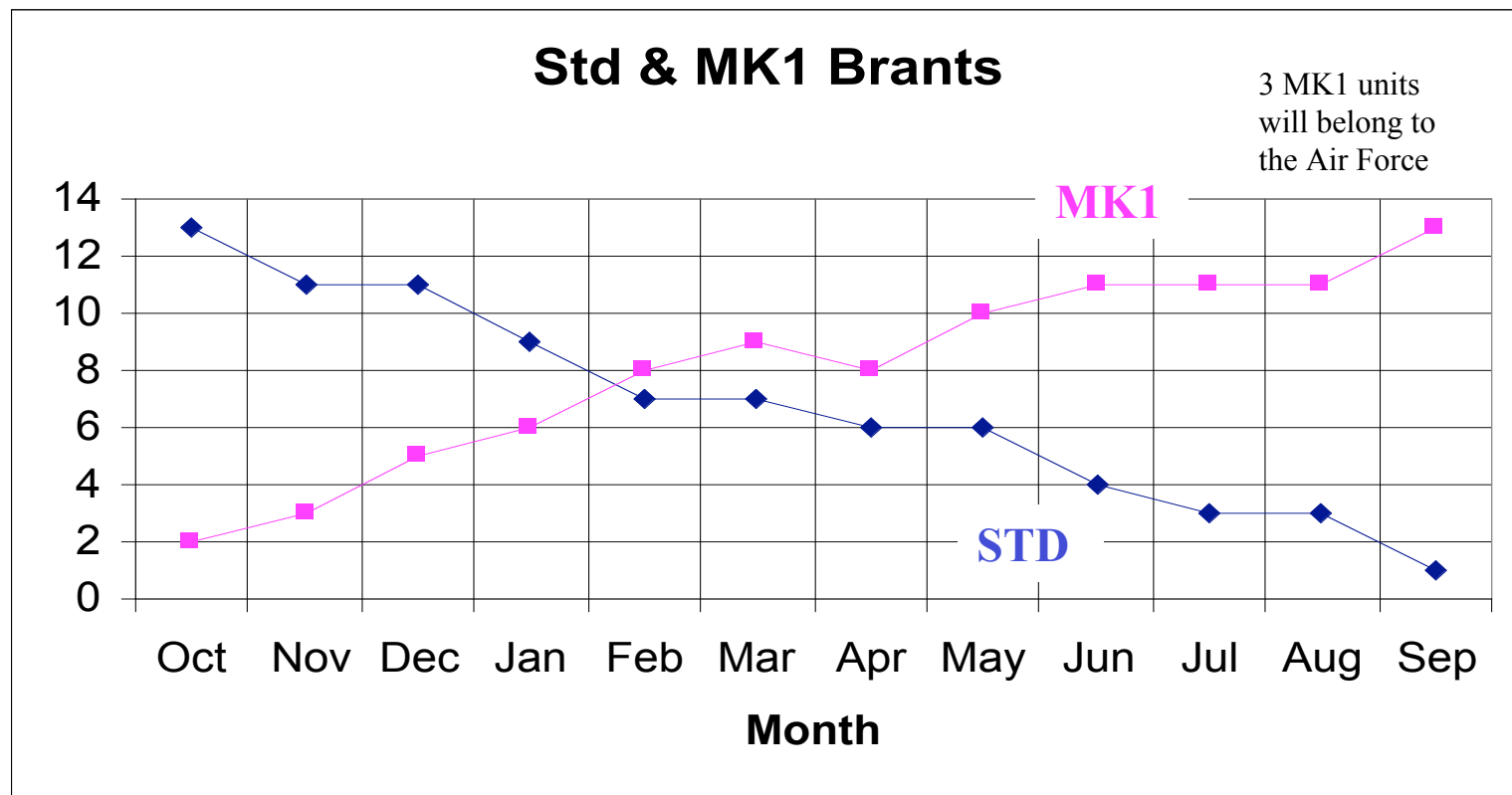
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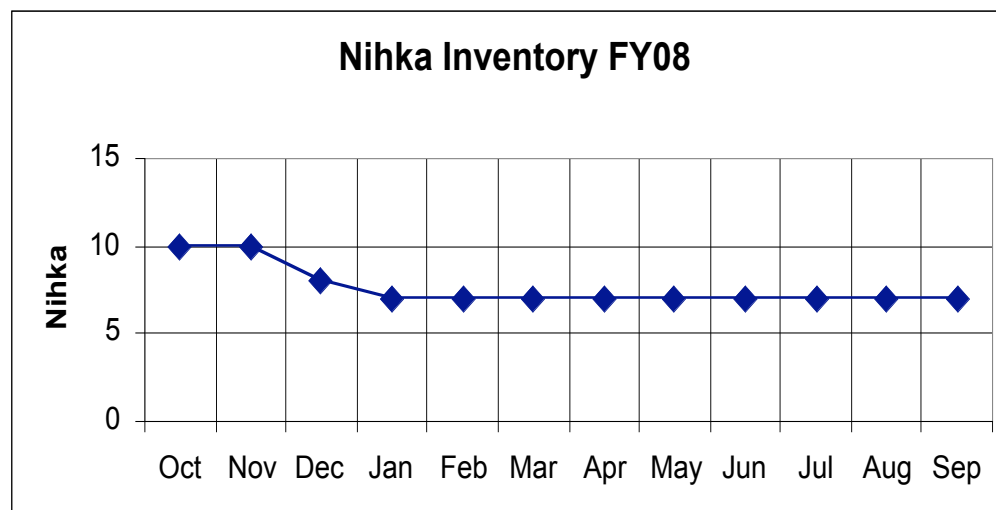
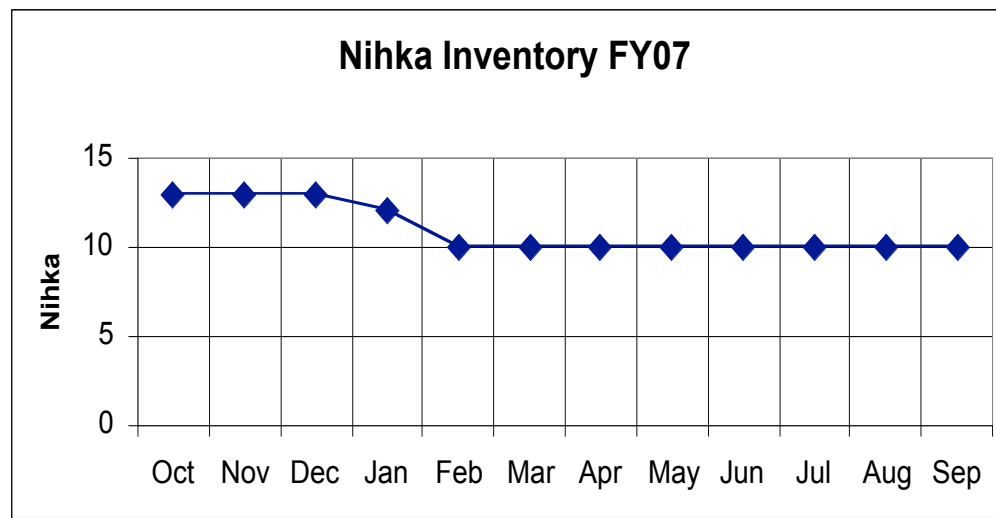
# FY07 Std & MK1 Brant Motor Inventory



MK1 inventory includes purchase of 5 units for reimbursable MARTI and only 3 MARTI flights in FY07. Inventory includes delivery of 10 SMD units associated with current buy and first 2 units of the new follow-on procurement.



# Nihka Motor Inventory



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## Other Motors



- Talos – 41
- Improved Orion – 59
- Patriots – 10 (to be delivered)
- MLRS – 200 (to be delivered)





# Findings from January 2006 SRWG



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# I. MLRS Rocket Development

*The SRWG is interested in the trades between subsystems and apogee performance. The payload environment is also of interest.*

- Development is underway
- DR is currently scheduled for Jan 10, 2007
- *Details provided later*



## II. NSROC ACS/Attitude/Trajectory Manual

*The SRWG can provide feedback on the manual. The SRWG would like more detail on the accuracies/limitations of GPS, C-band radars, TRADT, etc.*

- The SRPO welcomes the idea of feedback groups for the Sounding Rocket Trajectory and Attitude Analysis Manual
- The manual was not intended as a source for info on trajectory determination. The SRPO will consider a separate manual (or expansion) addressing positional data



### III. Appraisal of NSROC ACS and Attitude Systems

*The SRWG is interested in an assessment of the effectiveness of the transition from vendors to in-house. The SRWG is also interested in a comparison of performance between old and new systems*

- Difficult developing systems in parallel with operational missions (as has always been the case within the NSRP)
- Missions have the tendency to create a requirement before the systems are operational
  - Puts heavy strain on program resources
  - Results in development/testing compromises
  - Reduces efficiency of development effort
- Details on performance comparisons will be addressed in the afternoon (NSROC) session



## IV. Communication between NSROC and Experimenters During Design Period

- Design Freeze Dates
  - Attempted on Poker missions
    - Not very effective, but...
    - Still managed to hold most DR's near desired dates
  - Difficult to enforce, especially w/ foreign elements
- Improved Communication
  - Publish schedules upfront...
  - More TIM / status meetings tend to help keep things moving forward



**MAGELLAN**  
AEROSPACE CORPORATION

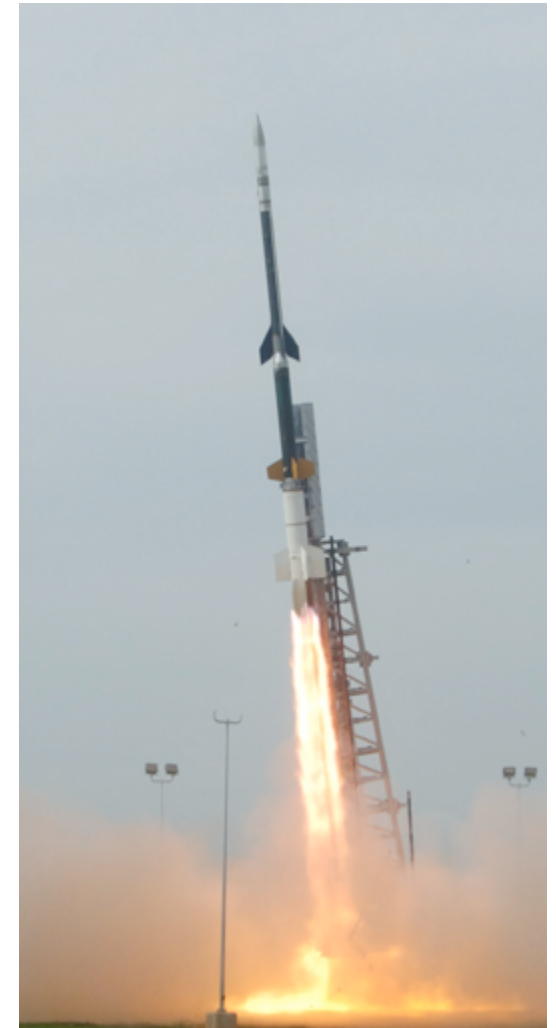
**BRISTOL AEROSPACE LIMITED**



# *Black Brant MK 1 Return-to-Flight Status Overview*

*SRWG Winter Session  
December 20, 2006*

John C. Hickman  
NASA Sounding Rockets  
Program Office



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# Executive Summary

- Black Brant RTF Team completed physical corrective actions and testing with successful flight demonstration of Black Brant XI from WFF on September 30, 2006
- All objectives were satisfied and comprehensive success criteria was met
  - New igniter design demonstrated
- Remaining tasks related to MIB
  - Formal closure of NAR action items
  - Formal closure of MIB
- MK 1 Brant's are back in production
  - Two units received and expended
  - Additional units on order



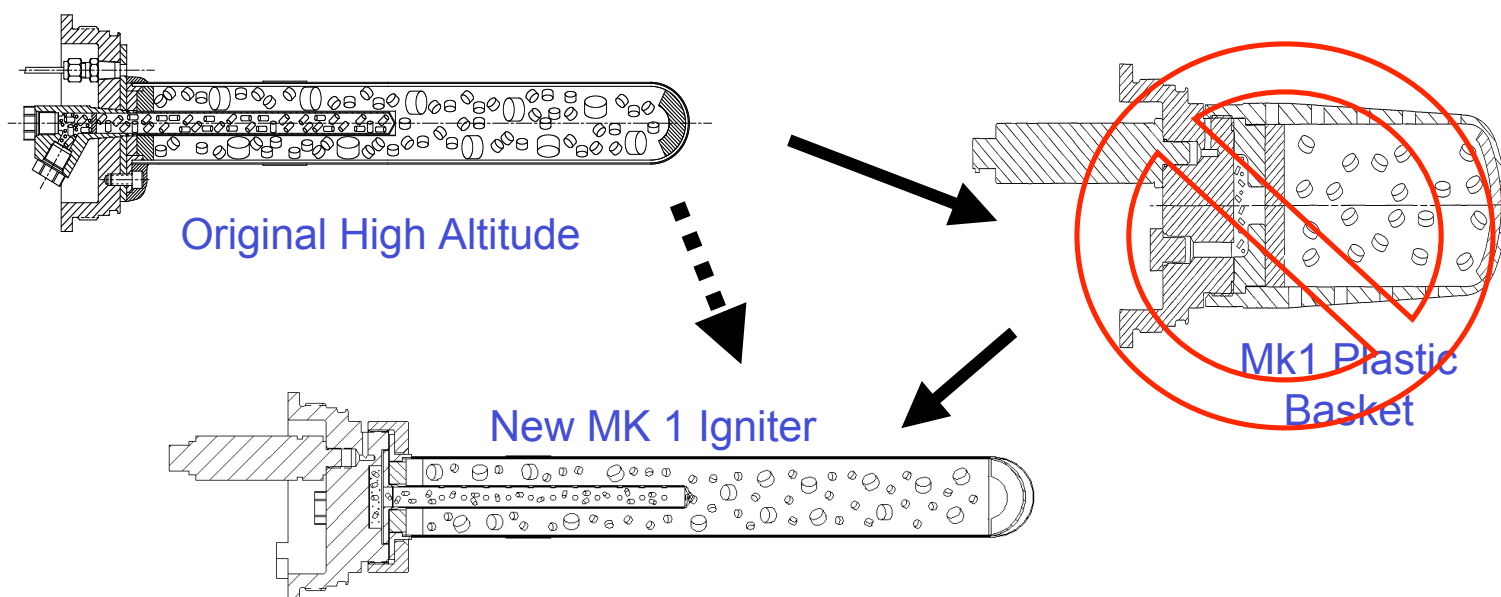
# Corrective Actions Overview

- Multi-organization team was assembled to develop corrective actions
  - NASA Sounding Rockets Program
  - Bristol Aerospace
  - NSROC
- Comprehensive design/test program implemented to address all findings of the MIB
- New igniter developed by Bristol and qualified through numerous tests
- Non-advocate review held with government, industry, & academic board
- Static fire conducted to demonstrate CA's and other concerns
- Test flight conducted as final phase of RTF project



# New Igniter Development

- MK1 plastic basket igniter design abandoned
- New design based on successful legacy Black Brant high altitude igniter design
- Redesign effort started at square #1
  - Ignitability requirements of new MK 1 propellant determined by extensive testing at China Lake, CA
  - Set performance requirements for new igniter – pressure & heat flux



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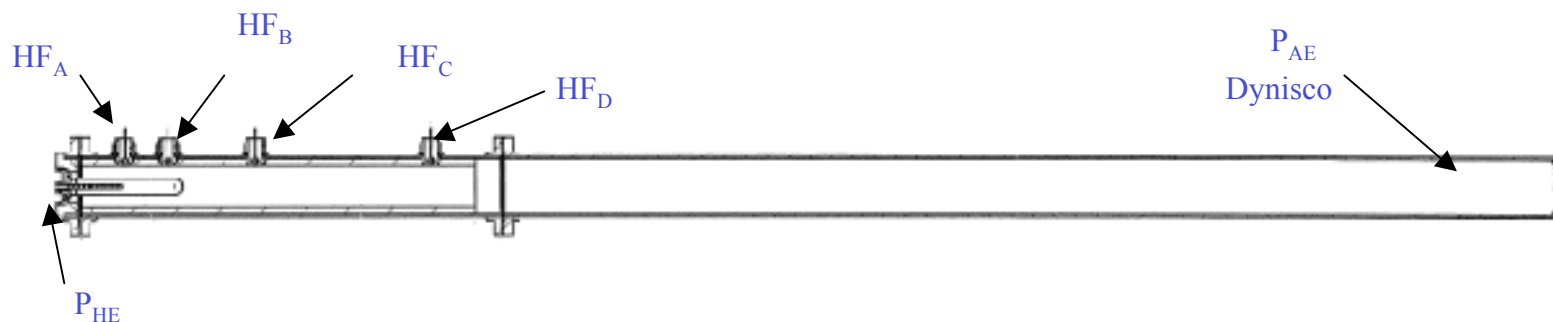
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# New Igniter Development

- Test cell designed by Bristol to verify new igniter performance
  - Pressure output (critical ignition parameter)
  - Heat flux output
- Igniter charge size and pellet ratio tweaked until performance requirements satisfied - ~20 firings
- Environmental qualification then undertaken followed by performance test in test cell





# Non-Advocate Review

- **Independent Non-Advocate Review was held May 2-3, 2006**
  - Review Panel comprised of experts from throughout country
    - Government, Academia, Consultants
  - Panel confident in new igniter design and test program
  - Recommended our project conduct an additional static fire of the new MK 1 motor
  - Static fire conducted at Edwards Rocket Lab on Aug. 30, 2006
  - Static fire was a comprehensive success
    - New igniter used & new production MK 1
    - Ignition pressure transient characterized and was within predicted limits – major concern of NAR Panel
    - Spent motor was returned to Bristol for dissection and analysis
- **RTF team in process of finalizing NAR action responses and will submit to panel for final closeout**
  - Must be done prior to MK 1 flight from Poker



# Accomplishments - Brant Static Firing



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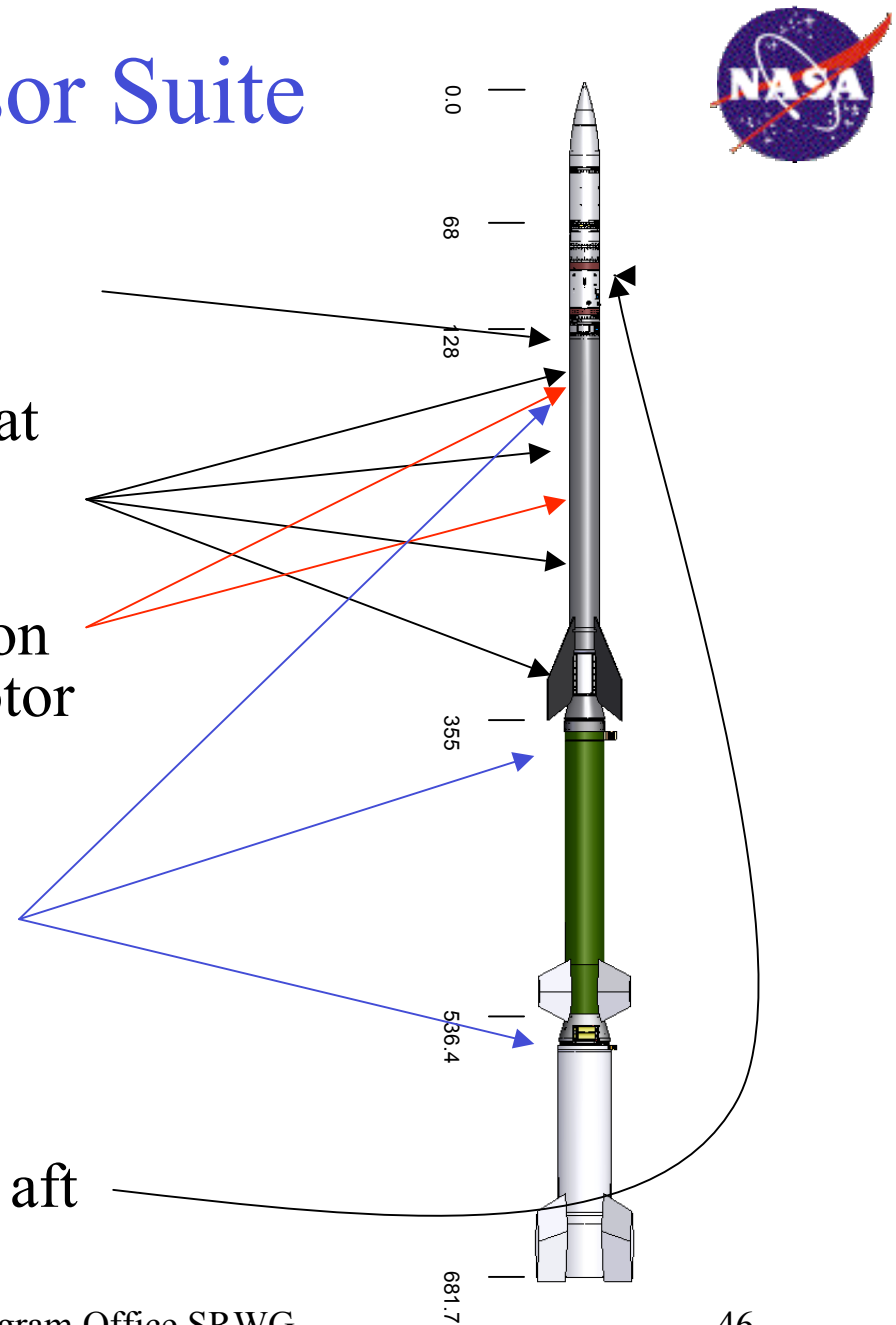
# Test Flight Overview

- Final phase of RTF project was demonstration of MK 1 in high altitude dynamic environment
- Black Brant XI flown from WFF on Sept 23, 2006
  - Ignition altitude was 47K feet
    - 5K feet higher than any previous Brant (including Lynch mission)
  - Extensive instrumentation incorporated to verify performance of motor.....see next slide
- Comprehensive success achieved
  - One issue with low chamber pressure observed
  - Appears total impulse was within specification
  - Still under review

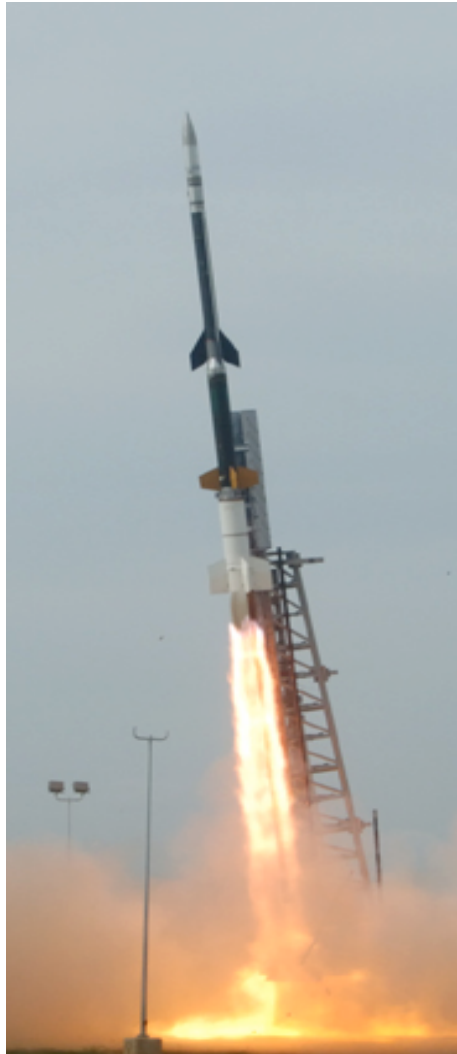


# Test Flight Sensor Suite

- Redundant pressure transducers
- 15 thermistors placed at strategic locations
- 3 strain gauges – two on head cap & one on motor case
- Vibrometers and microphones (vibro-acoustic information)
- Video camera looking aft



# Accomplishments - Brant Return to Flight



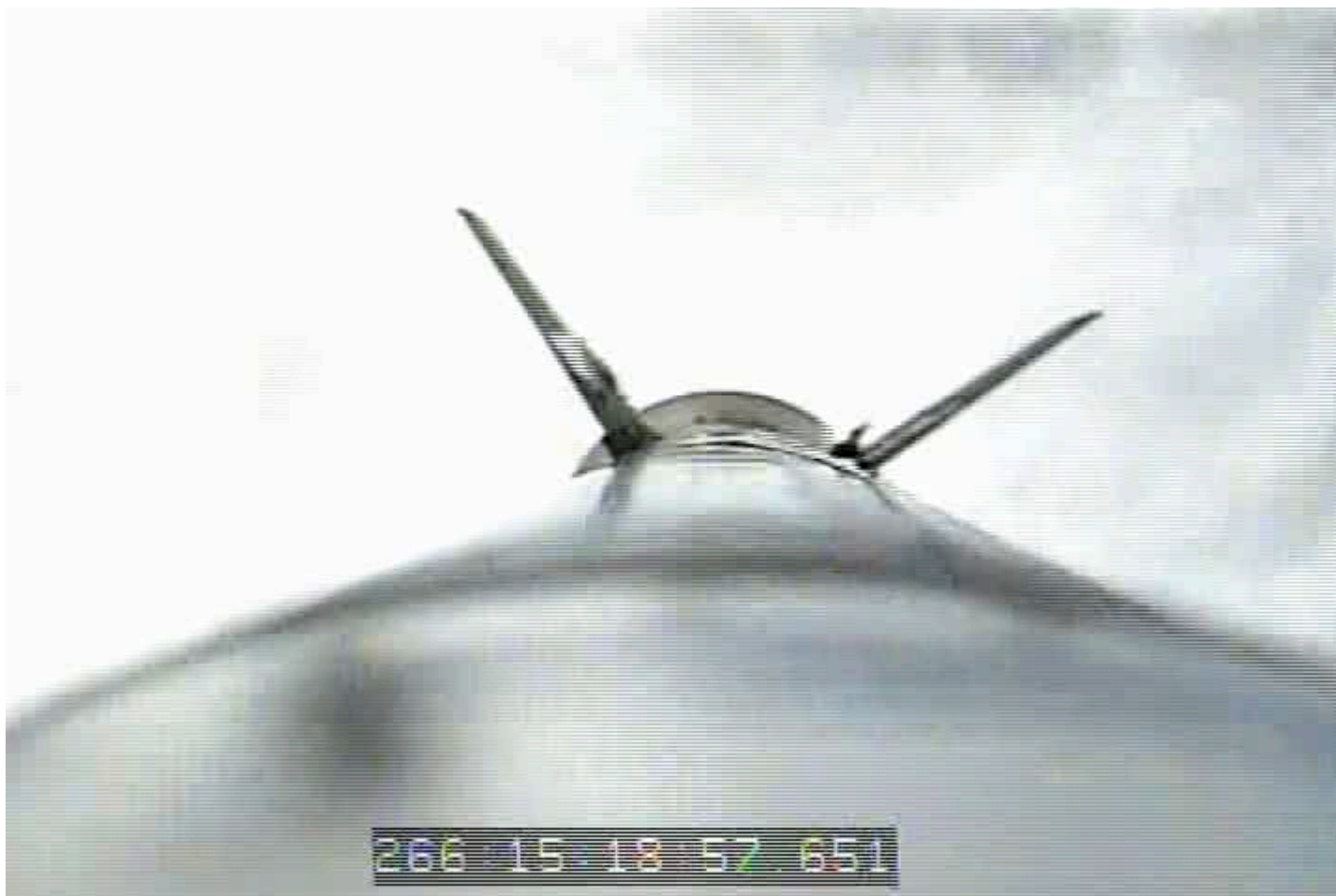
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# Boom Deployment



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## Results

- Highest ignition altitude to date (47kft)
  - New igniter design is very robust
- Acceleration impulse close to what was expected
- Motor chamber pressure did not match predicted and static firing
  - Results being assessed







# Black Brant MK 1 Production

- **Inventory of Brant motors is at historic low level**
- **Enough remain standard Brants to carry program through Spring '07**
- **Program decided to take risk and approved Bristol to continue MK 1 production during final phases of RTF project**
  - Necessary to ensure adequate motor supply maintained
  - New production MK 1's were utilized in static fire and test flight
- **First science mission to utilize MK 1 will be Larsen single stage Brant in Poker '07 campaign**
- **Delivery schedule of new motors phased over the next 12-18 months**
  - Program has order in place for 12 units (2 already consumed).....staggered delivery of new assets over next several month
  - Program directed NSROC to initiate purchase of additional 12 units to bring inventory up to adequate levels





# Mesquito Development

(Dave Krause)



December 20, 2006

Sounding Rocket Program Office SRWG  
Briefing

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# Next Generation ACS

(Brett Vincent)



December 20, 2006

Sounding Rocket Program Office SRWG  
Briefing

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## Project Objectives



Develop an ACS architecture that:

- Will be flexible, maintainable, and easily adaptable to meet the requirements of current and future missions
- Can be adapted to employ various types of sensor suites and actuators to meet diverse scientific objectives

# Concept



- “Modular” design – mate appropriate sensors and actuators to a common flight computer to meet specific mission needs
  - PC-104 form factor FC running RTLinux Free OS
  - Sensor interface cards as required
  - Microprocessor to control actuators
  - Modular SW
- New fine control actuators
  - Proportional valves
  - Small momentum wheels for fine control?





## FY2007 Efforts

- Flight Computer development
  - PC/104 x86 Derivative
  - ALERT (Aerospace Linux Environment Real Time)
    - A-squared library - Reusable abstraction layer
    - Native cross compilation
    - Once developed, low to no cost
  - Peripherals
    - 16x50 UARTS
    - Synchronous serial controllers
    - MIL-STD 1553
- As FC development matures, will “spin-off” FC to NSROC for incorporation into current systems



## FY2007 Efforts (cont.)

- Pneumatics design
  - Proportional valves
    - Single valve for both coarse and fine control
    - Single pressure regulator
  - Considering alternative valve configurations (i.e., skewed pitch and yaw nozzles for roll control)
- Control simulations
- Modular configuration designs